

---

## Safety of Urban Transport Users During the Covid-19 Pandemic

---

Submitted 02/08/20, 1<sup>st</sup> revision 10/09/20, 2<sup>nd</sup> revision 15/10/20, accepted 17/11/2020

Igor Betkier<sup>1</sup>

**Abstract:**

**Purpose:** The article investigates issues related to the safety of transport users commuting in urbanized areas using buses, trams, subway, vehicle sharing systems, taxicabs, or ride-sourcing/ridesharing apps during the Covid-19 pandemic.

**Design/Methodology/Approach:** The author surveyed city residents to identify their current transport safety-related preferences. Based on this survey results, the preferences identified were correlated with the actual measures undertaken by carriers to prevent virus transmission.

**Findings:** A detailed analysis has revealed that the measures that have been implemented not always correspond with expectations of transport users or even with actual needs arising from the current epidemiological situation.

**Practical Implications:** The analysis serves as a basis for evaluating the validity of guidelines and assessing the new safety standards developed by local authorities to protect the life and health of transport users. These standards could be maintained should subsequent waves of Covid-19 infections be experienced. They could also be implemented again if threats posed by other virus types need to be faced in the future.

**Originality/value:** The author compared both expected and actually implemented solutions with their effectiveness parameters, based on experimental results and foreign literature.

**Keywords:** Covid-19, public transport, urban transport, transport safety.

**JEL Code:** R1.

**Paper Type:** Research in Security Studies.

---

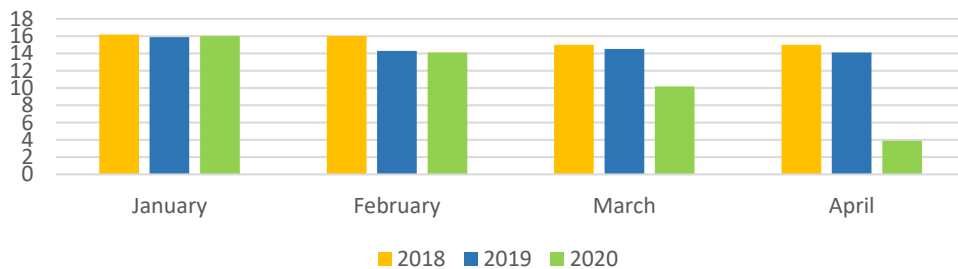
<sup>1</sup>Military University of Technology in Warsaw, Faculty of Security, Logistics and Management, Poland, [igor.betkier@wat.edu.pl](mailto:igor.betkier@wat.edu.pl);

## 1. Introduction

The intensive migration of the population, thanks to the developed passenger transport system, is nowadays the main source of risk for the transmission of infectious diseases and the formation of pandemics (Beaglehole and Bonita, 1993). Too late reaction to an outbreak makes it very difficult to stop the disease (Du *et al.*, 2020). Therefore, it is necessary to reduce people's mobility, depending on the epidemic's stage and area (Kraemer *et al.*, 2020; Chinazzi *et al.*, 2020). During an epidemiological threat or epidemic, even if an urban agglomeration is quarantined and transport corridors are cut off, population movements are necessary to maintain the community (Stjernborg and Mattison, 2016). As a result, urban transport is operated on a different basis, albeit without stopping it altogether.

The epidemic, and thus the restrictions introduced, are quite strongly affecting carriers' liquidity (ITF, 2020). Restrictions limiting the number of passengers to half the seats actually reduce capacity to a mere 15%. One of the agencies (Fitch Ratings, 2020) has updated the ratings of transport companies in Poland, based on the analysis of the number of passengers in January - April 2020 compared to 2018 - 2019. One of the assessed operators was Gdańskie Autobusy i Tramwaje (GAiT), for which the distribution of passengers is presented below.

**Figure 1.** Distribution of GAIiT passengers between January and April 2018 and 2020 [million]



**Source:** Fitch Ratings, 2020.

Analyzing Figure 1 shows that both January and February did not bring any change in the number of passengers. This is all the more important because, at the same time, the COVID-19 epidemic was gaining momentum in Europe, and border traffic was practically uncontrolled, which is necessary to effectively fight the pandemic (Hossain *et al.*, 2020). The situation changed significantly in March when the first cases of SARS-CoV-2 infection appeared in Poland. It is, among other things, the restrictions introduced that caused the number of passengers in March to fall by almost 30% compared to 2019. April brought an even greater decrease in the number of GAIiT users to 4 million passengers than more than 14 million, a reduction by over 70%. Such a drastic decline was undoubtedly also influenced by concerns about the pathogen (Mertens *et al.*, 2020). Poland's existing epidemiological situation is an

unprecedented event in recent decades, and its consequences have affected the entire economy, including the passenger transport segment (Musselwhite *et al.*, 2020).

## **2. Expectations of Urban Transport Users and Preventive Measures implemented to Counter COVID-19**

The Covid 19 epidemic has partially changed the safety aspect of transport from both service providers and users themselves. Until now, safety, as one of the quality criteria of the transport system (Józwiak and Betkier, 2018), has most often been considered in the context of the probability of a road event generating certain effects for the health and life of both drivers and passengers, and in the context of co-passenger behavior (Evans, 1994; Łukasik and Szymanek, 2012; Carr and Spring, 1993). The importance of public transport in transmitting infectious diseases has been widely recognized by societies in the Asia-Pacific region (Burgess and Horia, 2012). The reason for this is one of the highest rates of urbanization, population density, and experience, i.e., the SARS-CoV outbreak in 2002 (Lau *et al.*, 2003). Researchers from all over the world have repeatedly analyzed this phenomenon. Research has focused, among other things, on the possibility of droplet transmission in public transport and simulations for cities (Goscé and Johansson, 2018), or general analysis of the transmission routes of infectious diseases, which highlighted the role of public transport (Mossong *et al.*, 2008).

The study carried out by Zarząd Transportu Miejskiego Poznań (2019) shows that the possibility of contracting an infectious disease in Poland before the epidemic was not even considered a risk factor for public transport passengers. The majority of respondents were afraid of behaviors that did not comply with social norms, traveling at night, or too few passengers on the vehicle. The most desirable preventive measures for the respondents turned out to be a monitoring system, vehicle lighting, or the presence of other passengers.

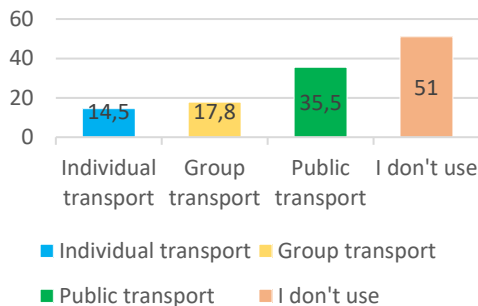
When traveling by means of a rental vehicle service with a driver, passengers' concerns are mainly related to the skills and verification of drivers (Quality Watch, 2019). Services based on mobile applications largely carry out a very general verification of their partners, with occasional loss of licenses due to public safety violations.

Companies offering services as part of the economy of sharing face users' concerns about the vehicle's technical condition (Public Consultation, 2017). The repeatedly rented vehicle is operated after a certain mileage or period of time, and each time the vehicle is returned by another user, its exact condition is uncertain. This is caused by failure to report faults by users as well as by misuse of vehicles.

In a survey carried out for the paper, from June 3 to 10, 2020, 304 respondents (n = 304) answered questions about their current preferences for urban transport safety from the point of view of the current epidemiological situation. The group has been

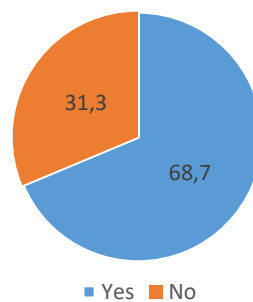
identified based on data from the report Europeans' Satisfaction with Urban Transport (2014). The respondents lived in large urban agglomerations between 18 and 39 years of age, which also accounted for the main share in the spectrum of urban transport solutions based on mobile applications (IPSOS, 2015). The distribution of users in the different categories, as well as their current approach to safety, is shown in Figures 2, 3, and 4 below.

**Figure 2.** Percentage of respondents declaring the use of a particular mode of transport [%]



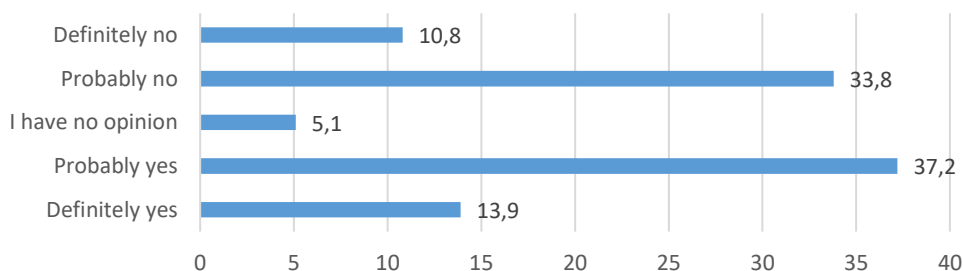
Source: Own elaboration.

**Figure 3.** Percentage of respondents declaring a reduction in journeys due to Covid-19 [%]



Source: Own elaboration.

**Figure 4.** Percentage of respondents declaring fear of getting infected during the journey [%]



Source: Own elaboration.

As shown in Figure 2, half of the respondents are not currently (June) using any means of urban transport. Moreover, as much as 68.7% of the respondents reduced the number of journeys connected with the Covid-19 epidemic. The impact can be considered on many levels. According to the survey entitled *Czas wolny Polaków podczas korawirusa* (Poles' free time at the time of coronavirus) (Presentmarzeń, 2020), in March, 66% of respondents worked remotely. Despite the gradual loosening of restrictions in Poland, some workers are still doing this kind of work. From the report, *Work in the era of coronavirus*. The new professional normality (Pracuj.pl,

2020) shows that 39.5% worked completely remotely in late April, and 21% partly remotely and partly at the company headquarters. This mode of employment was not the only factor that reduced the number of urban transport users. A large group of public transport passengers is learners who have switched to remote learning mode.

According to the survey conducted for the article, there is a bit more to it, namely security concerns. More than 50% of those surveyed stated that they were afraid of getting infected while using urban transport, of which 13.9% expressed a definite fear, as shown in Figure 4. 33.8% of the respondents are skeptical about the possibility of getting infected. In comparison, 11.8% do not see any risk of SARS-CoV-2 transmission. Of those who continue to use urban transport, the largest group uses public transport. More than a third of respondents travel by bus, tram, or underground, almost 18% travel by hired vehicles with a driver, and less than 15% rent vehicles as part of the sharing economy.

Counteracting the spread of the SARS-CoV-2 virus epidemic generated the need to implement changes in urban transport, both because of formal requirements and because passengers were concerned about travel safety. The general prevention measures implemented included awareness-raising, the obligation to cover faces, and maintaining a social distance (WHO, 2020; Ozili and Arun, 2020). Informing passengers about potential risks and current guidelines is done by displaying the Ministry of Health recommendations on monitors inside the vehicles. The obligation to wear face-covering has been in force in Poland since April 16. However, the material used and the way of covering are irrelevant. The required social distance is defined as the distance that needs to be maintained between persons who do not live together, significantly reducing the risk of coronavirus infection. In addition to these preventive measures, service providers have been given additional guidance to minimize the likelihood of transmission of the pathogen and encourage their services despite the epidemic.

## **2.1 Public Transport**

Public transport services are characterized, among other things, by the possibility to move large numbers of people using a single means of transport. This fact becomes a problem at the time of epidemic when the number of contacts must be kept to a minimum and closed rooms where no air exchange takes place must be avoided. What is more, because of the economic viability of using this type of transport it affects the largest number of people. This is also confirmed by the respondents' answers presented in Figure 2. The preventive measures applicable to this service group are as follows: Dedicated zones - In case of means of transport with semi-open cabs, carriers will designate a special zone behind the first row of seats which also prevents entry/exit through the first door, right next to the driver;

a) Reducing the number of passengers - Depending on the epidemic stage, the number of people in public transport varies. On March 24, the Polish government

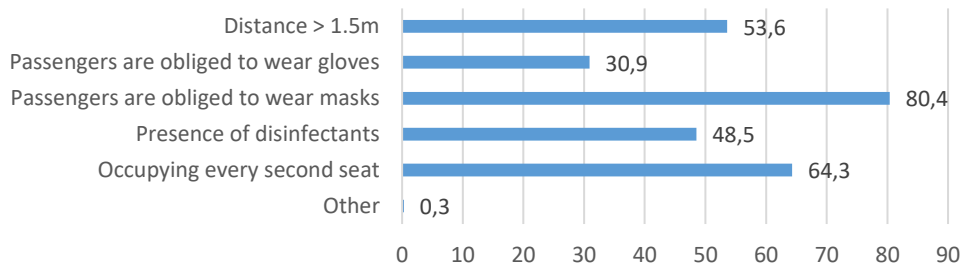
introduced a passenger limit for vehicles at 50% of the total number of seats. As of June 1, the number of passengers that may enter the vehicle is half the standard vehicle limit, taking into account both the seats and standing spots, in compliance with the rule that only half of the seats can be occupied;

b) Hand disinfectants - Some carriers have decided to install contactless dispensers. Such solutions are used in Szczecin and Poznań;

c) Vehicle washing/disinfection - Most carriers declare that their vehicles are disinfected daily, which does not really increase this activity's frequency. The difference lies in the type of agent used and the greater care taken to clean the surface that passengers come into contact with: handrails, seat backrests, punches, ticket machines, handles.

Figure 5 shows the respondents' preferences in the context of preventive measures that the service provider must ensure so that they use the public transport service.

**Figure 5.** *Percentage of respondents specifying individual preventive measures determining the use of public transport service [%]*



**Source:** *Own elaboration.*

As can be seen in Figure 5, respondents mostly expect their co-passengers to use masks. More than 80% of respondents expect such preventive measures. On the other hand, respondents pay a lot of attention to social distancing and therefore expect to maintain 1.5 meters distance (53.6% of respondents) and to occupy every second seat (64.3% of respondents). Almost half of the people described the presence of disinfectants as a necessity, and 30.9% that passengers are obliged to wear gloves, which indicates a fairly intense fear of contact with potentially infected surfaces. It is worth noting that the solutions mentioned are not applied on a mass scale, although they seem to be important for the passengers' sense of security.

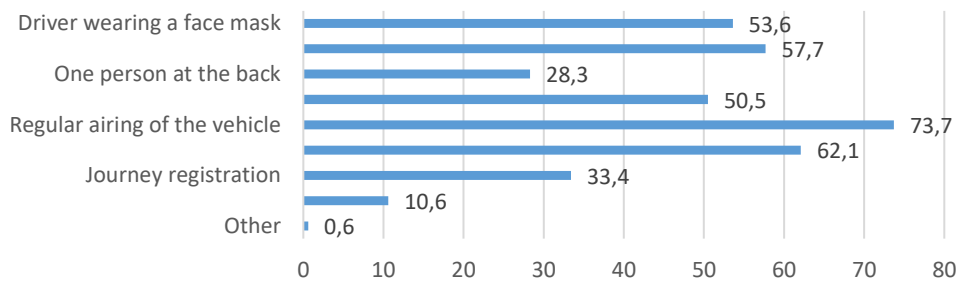
## 2.2 Group Transport

Driving a hired vehicle with a driver during the Covid-19 epidemic was in crisis, although some companies decided to continue operating despite adverse external factors. Therefore, it was necessary to take appropriate measures to protect the health of both passengers and drivers. The main measures to prevent infection in this transport group include:

- a) Reducing the number of passengers to a single person on the backseat couch - This solution was introduced by carriers who had previously offered to drive several unrelated persons traveling in the same direction;
- b) Separation screens - Plastic film screens appeared at some service providers as early as mid-March and were partially replaced by special plexiglass screens;
- c) Journey registration - Carriers provide their services with the support of mobile applications, and thus they can trace, based on the collected data, the potential virus spread route - directly between the driver and the passenger, and indirectly between passengers;
- d) Disinfecting/airing the vehicles - Service providers declare regular cleaning of seat belt buckles and handles and airing of vehicles after each journey, as well as cyclic ozonization of vehicles;
- e) Disinfectant to be made available in the passenger compartment.

Figure 6 shows respondents' preferences for safety in group transport vehicles.

**Figure 6.** *Percentage of respondents specifying individual preventive measures determining the use of group transport service [%]*



**Source:** *Own elaboration.*

Most of the respondents (73.7%) indicated the need for the regular airing of the vehicle. The vast majority of respondents see a further need to reduce the risk of droplet infection and require a driver's mask (53.6%) and a plexiglass/foil barrier (57.7%). A quantitatively similar group requires that hands need to be kept clean because it translates into making the payment only in the application (62.1% of respondents) and the presence of disinfectants (50.5%). Interestingly, respondents do not expect a lack of verbal communication (10.6% of respondents). More than a quarter of those surveyed require that only 1 passenger be driven at the back, and a third sees the need to register journeys to help trace the infection route. Vehicle ozonation was indicated as an additional solution (0.6%).

## 2.3 Individual Transport

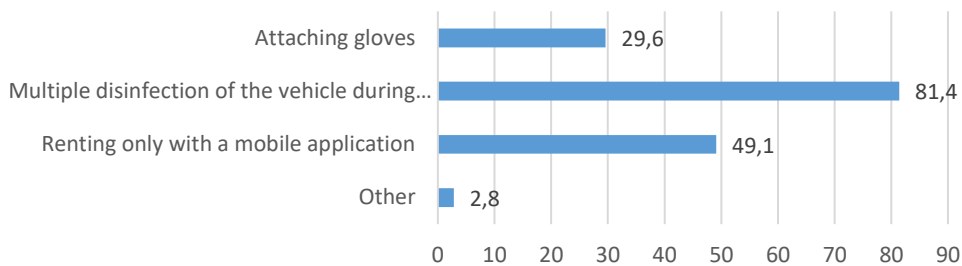
The specificity of vehicles used within car-sharing systems, urban bike-sharing systems, scooters, or motor scooters enables traveling without contact with other

people. However, in the case of the virus epidemic, the possibility of getting infected through contact with the surface that has a virus on it was underlined from the beginning. It was estimated that the virus could last on various surfaces from 2 hours to as much as 9 days (Kampf, Todt., Pfaender and Steinmann, 2020), and that is why many car rental companies had to stop their operations temporarily and when the restrictions were partly lifted, introduced the following preventive measures:

- a) Vehicle disinfection - Depending on the type of vehicle, cleaning is carried out at docking stations, parking areas or service stations;
- b) Rental only via mobile application - Devices supporting vehicle stations have been temporarily disabled;

Respondents' preferences for the preventive measures that need to be implemented in this transport group are presented below.

**Figure 7.** *Percentage of respondents specifying individual preventive measures determining the use of individual transport service [%]*



**Source:** Own elaboration.

The vast majority of respondents (81.4%) indicated disinfection as the most desirable action on the service provider. It should also be stressed that it is expected to be carried out several times a day since vehicles are repeatedly rented daily. Nearly half of the respondents (49.1%) require the possibility to rent a vehicle exclusively in a mobile application, and 29.6% would expect gloves to be attached to the vehicle. Among other solutions, respondents mentioned the necessity to install a dispenser with a disinfectant in the vehicle or at the rental place (2.8%).

### 3. Effectiveness of Preventive Measures on the Example of Urban Public Transport

The effectiveness of preventive measures is best assessed using the example of urban public transport, as it is mass transport and affects the largest number of people. On the other hand, when using this type of transport, passengers contact other passengers and touch various surfaces.



Recent studies show that covering the face is important to prevent SARS-CoV-2 infection. This is because the main mechanism of virus transmission is large droplets with a diameter of more than 0.1 mm and not aerosol droplets with a diameter of more than 10  $\mu\text{m}$  as previously thought. This is influenced by the fact that the highest expression of the ACE2 cellular receptor is in the nasal cavity (Sungnak et al., 2020). Larger particles are retained in the upper respiratory tract, allowing them to be blocked by masks, which are quite an effective physical barrier. Their actual effectiveness, depending on the standard, is described in the 2008 study. Its result is presented in the table below.

**Table 1.** Effectiveness of various types of masks in filtration of large aerosol droplets

Type of barrier	The number of particles entering through the mask	Particles produced in the environment	Number of particles excreted with cough	Particles leaking to the environment
Homemade mask	33	100 benchmark	100 benchmark	90
Surgical mask	25			50
FFP2 mask	1			30

**Source:** Van der Sande M., Teunis P., Sabel R. (2008).

As shown by the experiment results in Table 1, using a mask for personal protection is quite promising. Reduction of almost all large aerosol droplets for FFP2 masks, three times for a normal piece of material, and four times for a surgical mask provide significant protection against infection. In case of transmission of particles excreted by coughing, the protection is comparable to the effect of a 2 m distance, washing hands, and avoiding touching the face. This was found based on studies that determined the range of large aerosol droplets at 1.5 meters for exhalation and over 2 meters for coughing (Xie *et al.*, 2007).

The exact effectiveness of maintaining the distance between passengers on transport means it is not yet clear. Current studies show that maintaining a distance of more than 1 meter reduces infection risk to 2.6%. Reducing this distance increases the risk of infection to 12.8 %, while every additional meter up to 3 meters can reduce the risk of pathogen transmission by up to half (Chu *et al.*, 2020).

Traveling by public transport usually requires contact with different surfaces, from pressing the door openers or buttons used to notify the driver to use the handles or occupying the seats. Recent research shows that contact with the surface that has the SARS-CoV-2 virus on it is of marginal importance for further transmission of the pathogen. In the study, viral RNA was found on only 3% of the most frequently touched surfaces (handles, furniture) in households where at least one person was infected with Covid-19 (Döhla *et al.*, 2020).

Using studies (Chu *et al.*, 2020; Döhla *et al.*, 2020; van der Sande, Teunis and Sabel, 2008) and taking their results as corresponding only to the criterion under examination allowed to estimate an indicative likelihood of passengers getting infected on a public transport vehicle, with the following assumptions:

- 1) Windows of the vehicle are closed and there is no artificial air circulation;
- 2) A passenger with Covid-19 is present on the vehicle and generates the pathogen in such a way that it maintains a constant ratio of non-infective to infective airborne particles, and these environmental conditions are the same for all passengers;
- 3) The amount of the pathogen needed for infection is constant for everyone;
- 4) The exposure time is averaged according to the assumptions of source studies (we assume that it was the same for all studies);
- 5) All passengers have masks of one type or no masks at all;
- 6) This preventive measure for a healthy passenger is the only one used at the time;
- 7) As the infected person leaves the vehicle, the number of particles containing the pathogen falls to zero.

**Table 2.** Likelihood of infection by individual preventive measures [%]

			Is there a passenger with Covid-19 in the vehicle?				No
			Yes				
			Does the infected passenger have a mask?				
Type of mask	Homemade	Surgical	FFP2	No			
Possession of a mask*	Yes	Homemade	5.17	2.87	1.72	5.74	
		Surgical	3.92	2.18	0.08	4.35	
		FFP2	0.16	0.005	0.003	0.17	
	No	15,66	8.7	5.22	17.4		
Maintaining distance**	Yes	>1m	2.34	1.3	0.78	2.6	
		2m	1.17	0.65	0.39	1.3	
		3m	0.59	0.33	0.2	<1	
	No	11,5	6.4	3.84	12.8		
Surface contact***	Yes	2,7	1.5	0.9	3		
	No	0					

≤0.5
  0.5-2
  2-3
  3-5
  5-10
  10-15
  >15

\*Estimated values assuming that the reference value for particles in the environment corresponds to the likelihood of getting infected according to van der Sande, Teunis and Sabel (2008), and the effectiveness of the masks corresponds to the values from Chu *et al.* (2020) studies;

*\*\*Estimated values for unchanging distance from other passengers during the journey, in an environment where the likelihood of getting infected is determined according to Chu et al. (2020), for the effectiveness of masks according to van der Sande, Teunis and Sabel (2008);*

*\*\*\*Estimated values based on Döhl et al. (2020) studies, depending on the amount of excreted particles from the point of view of effectiveness of masks of different types according to van der Sande, Teunis and Sabel (2008), assuming that each contact with the surface that has the pathogen on it results in infection.*

**Source:** *Elaborated based on Chu et al., 2020; Döhla et al., 2020; van der Sande, Teunis and Sabel, 2008.*

As shown in Table 2, the likelihood of infection, depending on the preventive measure adopted, is quite wide. If a healthy passenger is not wearing a mask, while the person around him or her is infected with SARS-CoV-2 and is not wearing a mask, it results in almost 1 in 6 cases of disease transmission. It is worth comparing two scenarios - one in which the passenger is not wearing a mask, but the one spreading the infection is wearing it and the other way round.

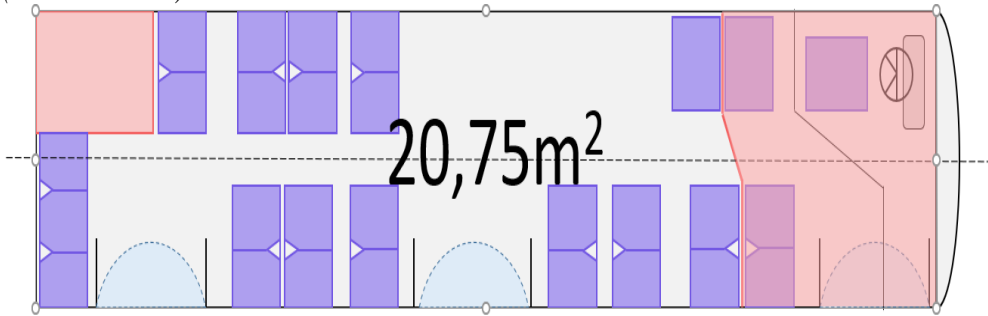
Depending on the type of mask, in the former case, the likelihood of infection is between 5.22% and 15.66%, while in the latter, it is only 0.17% to 5.74%. At this point, it should also be stressed that the likelihood of infection for a homemade mask type, while it is worn by both the healthy and infected person, is 5.17%. In the case of homemade masks, this fact gives the wearer a false sense of security when they see other passengers wearing similar types of masks. At the same time, the real probability of infection remains at a similar level.

The different mask combinations for ordinary and infectious passengers range from 0.003% for FFP2 masks to 5.17% for homemade masks. It is incomparably smaller and much smaller than if the guidelines were not respected at all. In the case of a preventive measure in distancing, the likelihood of infection is as high as 12.8% if the distance from a Covid-19 patient is less than 1m, and he is not equipped with a mask. Depending on the type of mask worn and the patient's distance, the likelihood of pathogen transmission ranges from 3.84 to 11.5% for non-observance of the distance and 0.2 to 0.59% for a 3 m distance.

In case of contact with the surface with the pathogen on it, the risk of infection seems quite negligible. Depending on the patient's type of mask, it may reach values from 0.9 to 3%. Still, it should be stressed that contact with the surface alone does not result in infection, and the transmission of the virus most probably occurs upon contact with aerosol.

To assess the practical likelihood of infection in public transport, several scenarios have been analyzed for the Solaris Urbino 12 bus, which is among Miejskie Zakłady Autobusowe in Warsaw, while using the guidelines for public transport in Poland after June 1. A diagram of the bus is shown in Figure 8.

**Figure 8.** Diagram showing the distribution of seats in the Solaris Urbino 12 vehicle (ZMA Warsaw)



**Source:** Own elaboration.

By analyzing the space available to passengers, excluding the engine compartment and the area behind the driver, the usable space was determined to be 20.75 m<sup>2</sup>. Depending on the stage of the epidemic and the degree of vehicle occupancy, this space has a certain number of passengers. The occupancy rate of a vehicle is defined as the number of passengers present in the vehicle to the number of seats provided in the technical specification expressed as a percentage.

At the time of strictest restrictions, 16 people could be present simultaneously in the Solaris Urbino 12 vehicle, which corresponded to 25% of the vehicle's occupancy rate, with 1.29 m<sup>2</sup> per passenger results in a social distance of 1.14 meters. Current regulations reduce this distance to 0.8 meters with 50% of the vehicle's occupancy rate. Still, it is important to be aware that during peak hours, if the guidelines are not enforced, the vehicle's occupancy rate can be over 100%. The distances between passengers can be reduced to as much as 0.5 meters.

The likelihood of infection for the Solaris Urbino 12 vehicle will be determined based on the values in Table 2 using the formula below:

$$P_i = 1 - (1 - P_m)(1 - P_d)(1 - P_t) \quad (1)$$

where:

$P_i$  - likelihood of SARS-CoV-2 infection,

$P_m$  - likelihood of infection in the absence or use of one of the mask types,

$P_d$  - likelihood of infection in the absence of or while maintaining a certain distance,

$P_t$  - likelihood of infection through contact with the surface which has the virus on it.

The likelihood has been calculated for 4 scenarios, using the previously made assumptions and assuming that the change in the likelihood of infection depending on the distance is linear between 0 and 1 meter, 1 and 2 meters, etc.:

1) Regardless of the vehicle occupancy rate, passengers are not wearing masks, are at minimum distances from each other, and come into contact with the surface that has the pathogen on it;

2) All passengers have homemade masks, are maintaining a distance of 2 meters, and are not touching any components in the vehicle;

3) All passengers, except the infectious person, are wearing a homemade mask, maintaining a distance appropriate to a given vehicle occupancy rate, and are not touching any components in the vehicle;

4) All passengers are wearing a homemade mask, maintaining a distance appropriate to

a given vehicle occupancy rate and are not touching any components in the vehicle.

The results are presented in Table 3.

**Table 3.** *Likelihood of infection for different vehicle occupancy rates [%]*

Vehicle occupancy rate	Number of persons	Space per 1 person [m <sup>2</sup> ]	Distance between passengers [m]	1) [%]	2) [%]	3) [%]	4 [%]
25%	16	1.297	1.14	30	6.28	8.02	7.17
<b>50%</b>	<b>32</b>	<b>0.648</b>	<b>0.80</b>			<b>10.11</b>	<b>9.13</b>
75%	48	0.432	0.66			11.46	10.34
100%	64	0.324	0.57			12.33	11.12
125%	80	0.259	0.51			12.89	11.65

≤10    10-20    >20

**Source:** *Own elaboration.*

Analyzing the results from Table 3 shows how important it is to respect the implemented guidelines in preventing the development of the epidemic and protecting passengers' health. It can be assumed that the likelihood of infection in public transport is five times higher and reaches 30% if the Ministry of Health and WHO's recommendations are not respected. On the other hand, a 6.28% likelihood of getting infected with these preventive measures when a Covid-19 infected person is in the immediate vicinity is significant.

Unfortunately, with a 50% vehicle capacity rate, it is impossible to maintain the distance specified in the guidelines, and the likelihood of infection in this variant is about 10%. With no respect for the number of people in the vehicle during rush hours, it may even be 13%. It is worth noting that with the duration of the epidemic, even if the restrictions are partially maintained, they may be underestimated by passengers.

Interestingly, the absence of a mask in the infectious passenger does not significantly increase infection likelihood. The change in the result is only 1 percent, underlining the importance of wearing a mask as a preventive measure, over maintaining a distance. The range of likelihood of infection for vehicle capacity rate 25 - 125% if the guidelines are respected to the extent possible ranges from 7.17 to 11.65%. In a

similar case, when the infectious person is not wearing a mask, it ranges from 8.02 to 12.89%.

#### **4. Conclusions**

The protection against infection is in line with both passengers' expectations and carriers' interest in ensuring the safety of users while maintaining the quality of the transport service. The survey shows that although some restrictions have been reduced, passengers still have a conservative approach to urban transport and if they are to use it, expect a wide range of solutions to reduce the risk of infection. This is due to the fact that there was information chaos during the epidemic, and the results of research on the previously unknown virus had yet to be presented.

Research suggests that the riskiest is in contact with the infected person, who generates aerosol droplets containing the pathogen into the environment. To compare the risk of virus transmission in a vehicle, it is important to know that the actual epidemiological situation influences the infection. For example, on a Polish scale, the likelihood that an infected person is present in a Solaris Urbino 12 vehicle carrying 50% of passengers is only 2.6% (June). Of course, it should be assumed that the reported number of infected people is only part of the total number of carriers. The probability of meeting a patient should be considered in terms of estimated values presented in the article.

In the real situation, it is necessary to consider that the amount of pathogen required for infection varies and that the fact that the patient is present in another part of the vehicle significantly reduces the likelihood of virus transmission. It is impossible not to mention here the role of face-covering in reducing the risk of infection. The analysis has identified this preventive measure as the most effective against SARS-CoV-2. Wearing a mask is a decision taken by the passenger, and the distance from other people is variable due to the movement of passengers in the vehicle.

The scenarios analyzed showed that the combination of wearing a mask with maintaining a distance is the most effective one, with the type of masks worn by passengers being able to reduce the likelihood of infection many times (sometimes even more than a thousand times) both by reducing the emission of the pathogen into the environment and by creating a barrier for particles that can enter the upper respiratory tract from the environment. Taking all aspects into account, the riskiest is the use of public transport. In many cases, it is difficult to maintain a safe distance, significantly reducing the risk of infection in a situation when passengers are wearing plain-type masks.

On the other hand, passengers' preventive measures in the form of using every second seat or wearing gloves often do not correspond to the actual risk of developing the disease. Firstly, the seating arrangement in public transport vehicles often does not guarantee a distance of more than 1.5 meters between passengers. Moreover, it turns

out that the fear of infection through contact with the surface that has the pathogen on it is greatly exaggerated. The reason is that the virus interferes with the organism, which is part of the upper respiratory tract, and the amount of pathogen deposited on the most frequently touched objects. Means of individual transport, where the risk comes down to contact with the infected surface only, can easily be considered the safest. The actual risk of virus transmission occurs if the patient is present in the immediate environment.

Preventative measures in the form of frequent vehicle disinfection appear to be clearly satisfactory in this urban transport segment. Considering the analysis of the likelihood of infection in public transport, it can be determined that vehicles hired with a driver provide some alternative to buses, trams, and underground, significantly reducing the risk of infection. A tight separation of the passenger and driver spaces seems particularly effective. In the event of an epidemic developing, solutions for separating public transport passengers can be considered, and the extent to which verbal communication may affect the distribution of the pathogen to the environment should be assessed and the precise impact of exposure time on the likelihood of infection.

Due to the high effectiveness of masks, consideration should be given to raising their standard among passengers, among others, through information campaigns and mass production of surgical or FFP2 masks locally, increasing their availability in the market. Urban transport as a result of the Covid-19 epidemic has had to face passengers concerns (it has to be assumed that they will change depending on the stage of the epidemic) and thus the reduction in the number of users, which results in a drop in revenue while incurring the costs of adaptation to the new reality. However, prevention-based on responsible behavior of passengers and effective, scientifically based preventive measures can prove its worth for both new waves of the disease and new types of viruses while maintaining a satisfactory level of security in urban transport.

## References:

- Beaglehole, R., Bonita, R., Kjellström, T. 2006. Basic epidemiology. World Health Organization.
- Burgess, A., Horii, M. 2012. Risk, ritual and health responsabilisation: Japan's 'safety blanket' of surgical face mask-wearing. *Sociology of Health & Illness*, 34, 1184-1198.
- Carr, K., Spring, G. 1993. Public transport safety: A community right and communal responsibility. *Crime Prevention Studies*, 1, 147-155.
- Chinazzi, M., Davis, J. T., Ajelli, M., Gioannini, C., Litvinova, M., Merler, S., y Piontti, A. P., Mu, K., Rossi, L., Sun, K., Viboud, C., Xiong, X., Yu, H., Halloran, M. E., Longini Jr., I.M., Vespignani, A., 2020. The effect of travel restrictions on the spread of the 2019 novel coronavirus (COVID-19) outbreak. *Science*, 368, 395-400.
- Chu, D.K, Akl, E.A, Duda, S., Solo, K., Yaacoub, S., Schünemann, H.J. 2020. Physical distancing, face masks, and eye protection to prevent person-to-person transmission of SARS-CoV-2 and COVID-19: a systematic review and meta-analysis. *The Lancet*.

- Döhla, M., Wilbring, G., Schulte, B., Kümmerer, B.E., Diegmann, C., Sib, E., Richter, E., Haag, A., Engelhart, S., Eis-Hübinger, A.M., Exner, M., Streeck, H., Schmithausen, R. M. 2020. SARS-CoV-2 in environmental samples of quarantined households. medRxiv.
- Du, Z., Wang, L., Cauchemez, S., Xu, X., Wang, X., Cowling, B.J., Mayers, L.A. 2020. Risk for Transportation of Coronavirus Disease from Wuhan to Other Cities in China. *Emerging Infectious Diseases*, 26(5), 1049-1052.
- European Commission, Directorate-General Mobility and Transport. 2014. Europeans' Satisfaction with Urban Transport – Flash Eurobarometer 382a.
- Evans, A.W. 1994. Evaluating public transport and road safety measures. *Accident Analysis & Prevention*, 26, 411-428.
- Goscé, L., Johansson, A. 2018. Analysing the link between public transport use and airborne transmission: mobility and contagion in the London underground. *Environ Health*, 17.
- GUS. 2020. The impact of the COVID-19 epidemic on selected elements of the labor market in Poland in the first quarter of 2020.
- Hossain, M.P., Junus, A., Zhu, X., Jia, P., Wen, T. H., Pfeiffer, D., Yuan, H. Y. 2020. The effects of border control and quarantine measures on global spread of COVID-19. medRxiv.
- Huang, S. 2020. COVID-19: Why We Should All Wear Masks – There Is New Scientific Rationale. Medium.
- ITDP. 2020. Institute for Transportation & Development Policy: Post-Pandemic, Chinese cities gradually reopen transport networks.
- ITF. 2020. International Transport Forum. Covid-19 Transport Brief – Transport Policy Responses to The Coronavirus Crisis.
- Józwiak, A., Betkier, I. 2018. Ocena działania miejskiego systemu transportowego carsharing w modelu free-floating w Warszawie. *Systemy Logistyczne Wojsk*, 48, 99-111.
- Kampf, G., Todt, D., Pfaender, S., Steinmann, E. 2020. Persistence of coronaviruses on inanimate surfaces and their inactivation with biocidal agents. *Journal of hospital Infection*, 104(3), 246-251. <https://doi.org/10.1016/j.jhin.2020.01.022>.
- Konsultacje Społeczne. 2017. Raport - Toruński Rower Miejski od 2018 r. Konsultacje społeczne w sprawie lokalizacji stacji roweru miejskiego.
- Kraemer, M.U.G., Yang, C.H., Gutierrez, B., Wu, C.H., Klein, B., Pigott, D.M., Open COVID-19 Data Working Group, du Plessis, L., Faria, N.R., Li, R., Hanage, W. P., Brownstein, J. S., Layan, M., Vespignani, A., Tian, H., Dye, C., Pybus, O.G., Scarpino, S.V. 2020. The effect of human mobility and control measures on the COVID-19 epidemic in China. *Science*, 368, 493-497. <https://doi.org/10.1101/2020.03.02.20026708>.
- Kratzel, A., Steiner, S., Todt, D., V'kovski, P., Brüggermann, Y., Steinmann, J., Steinmann, E., Thiel, V., Pfaender, S. 2020. Temperature-dependent Surface stability of SARS-CoV-2. *Journal of Infection*.
- Lau, J., T., F., Yang, X., Tsui, H., Kim, J.H. 2003. Monitoring community responses to the SARS epidemic in Hong Kong: from day 10 to day 62. *J Epidemiol Community Health*. 57, 864-870.
- Łukasik, Z., Szymanek, A. 2012. Safety and risk in road traffic: Selected problems. *Transport problems*, 7, 83-94.
- Management of Covid-19: Guidelines for public transport operators, Advancing Public Transport.



- Mertens, G., Gerritsen, L., Duijndam, S., Saleminck, E., Engelhard, I.M. 2020. Fear of coronavirus (COVID-19): Predictors in an online study conducted in March 2020. *Journal of Anxiety Disorders*, 74, 102258.
- Morawska, L., Johnson, G. R., Ristovski, Z. D., Hargreaves, M., Mengersen, K., Corbett, S., Chao, C.Y.H., Li, Y., Katoshevski, D. 2009. Size distribution and sites of origin of droplets expelled during expiratory activities. *Journal of Aerosol Science*, 40(3), 256-269.
- Mossong, J., Hens, N., Jit, M., Beutels, P., Auranen, K., Mikolajczyk, R., Massari, M., Salmaso, S., Tomba, G.S., Wallinga, J., Heijne, J., Sadkowska-Todys, M., Rosinska, M., Edmunds, W.J. 2008. Social Contacts and mixing Patterns Relevant to the Spread of Infectious Diseases. *PLOS Medicine*, 5, e74.
- Musselwhite, C., Avineri, E., Susilo Y.O. 2020. Editorial JTH 16 – The Coronavirus Disease COVID-19 and implications for transport and health. *Journal of Transport & Health*, 16, 100853.
- Ozili, P.K., Arun, T. 2020. Spillover of COVID-19: Impact on the Global Economy. *SSRN Electronic Journal*.
- Pracuj.pl. 2020. Raport - Praca w dobie koronawirusa. Nowa normalność zawodowa.
- Prezentmarzeń. 2020. Czas wolny Polaków podczas koronawirusa – sonda.
- van der Sande, M., Teunis, P., Sabel, R. 2008. Professional and Home-Made Face Masks Reduce Exposure to Respiratory Infections among the General Population. *PLoS ONE*, 3.
- Stadnytskyi, V., Bax, E.C., Bax, A., Anfinrud, P. 2020. The Airborne Lifetime of Small Speech Droplets and Their Potential Importance in SARS-CoV-2 Transmission. *PNAS*, 117, 11875-11877.
- Stjernborg, V., Mattison, O. 2016. The role of Public Transport in Society – A Case Study of General Policy Documents in Sweden. *Sustainability*, 8(11), 1120.
- Sungnak, W., Huang, N., Bécavin, C., Berg, M., Queen, R., Litvinukova, M., Talavera-López, C., Maatz, H., Reichart, D., Sampaziotis, F., Worlock, K.B., Yoshida, M., Barnes, J.L. and HCA Lung Biological Network. 2020. SARS-CoV-2 entry factors are highly expressed in nasal epithelial cells together with innate immune genes. *Nature Medicine*, 26, 681-687.
- WHO. 2020. Coronavirus disease (COVID-19) advice for the public.
- Wölfel, R., Corman, V.M., Guggemos, W., Sailmaier, M., Zange, S., Müller, M.A., Niemeyer, D., Jones, T.C., Vollman, P., Rothe, C., Hoelscher, M., Bleicker, T., Brünink, S., Ehmann, E., Zwirgmaier, K., Drosten, C., Wendtner, C. 2020. Virological assessment of hospitalized patients with COVID-2019. *Nature*, 581, 465-469.
- Xie, X., Li, Y., Chwang, A.T.Y., Ho, P.L., Seto, W.H. 2007. How far droplets can move in indoor environments – revisiting the Wells evaporation – falling curve. *Indoor Air*, 17, 211-225.
- ZTM Poznań. 2019. Wyniki badania ankietowego dotyczącego poczucia bezpieczeństwa pasażerów korzystających z komunikacji miejskiej organizowanej przez ZTM w Poznaniu.